

A Transoceanic Aerobiology Biodiversity Study (TABS) to Characterize Microorganisms in Asian and African Dust Plumes Reaching North America

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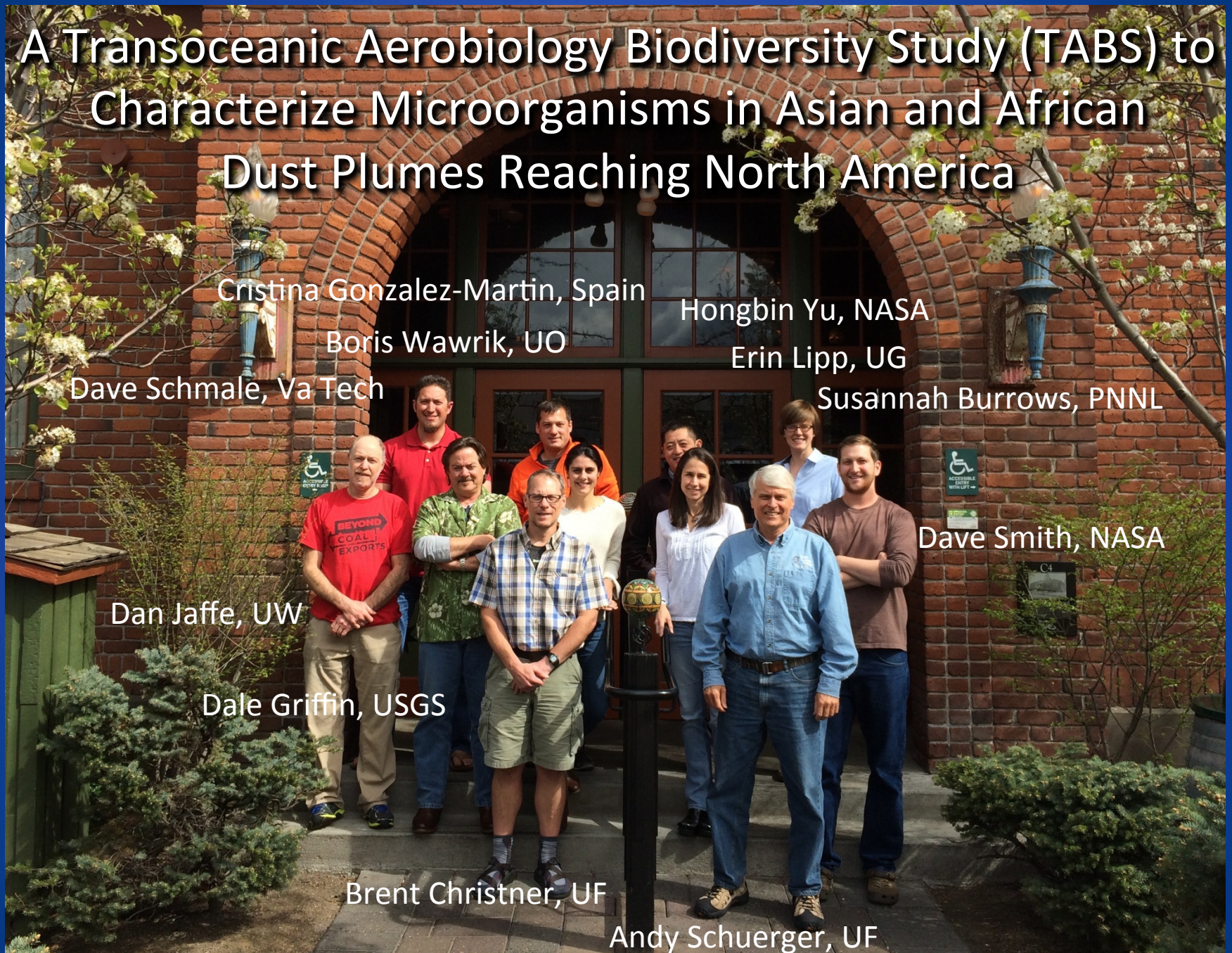
Dan Jaffe, UW

Dave Smith, NASA

Dale Griffin, USGS

Brent Christner, UF

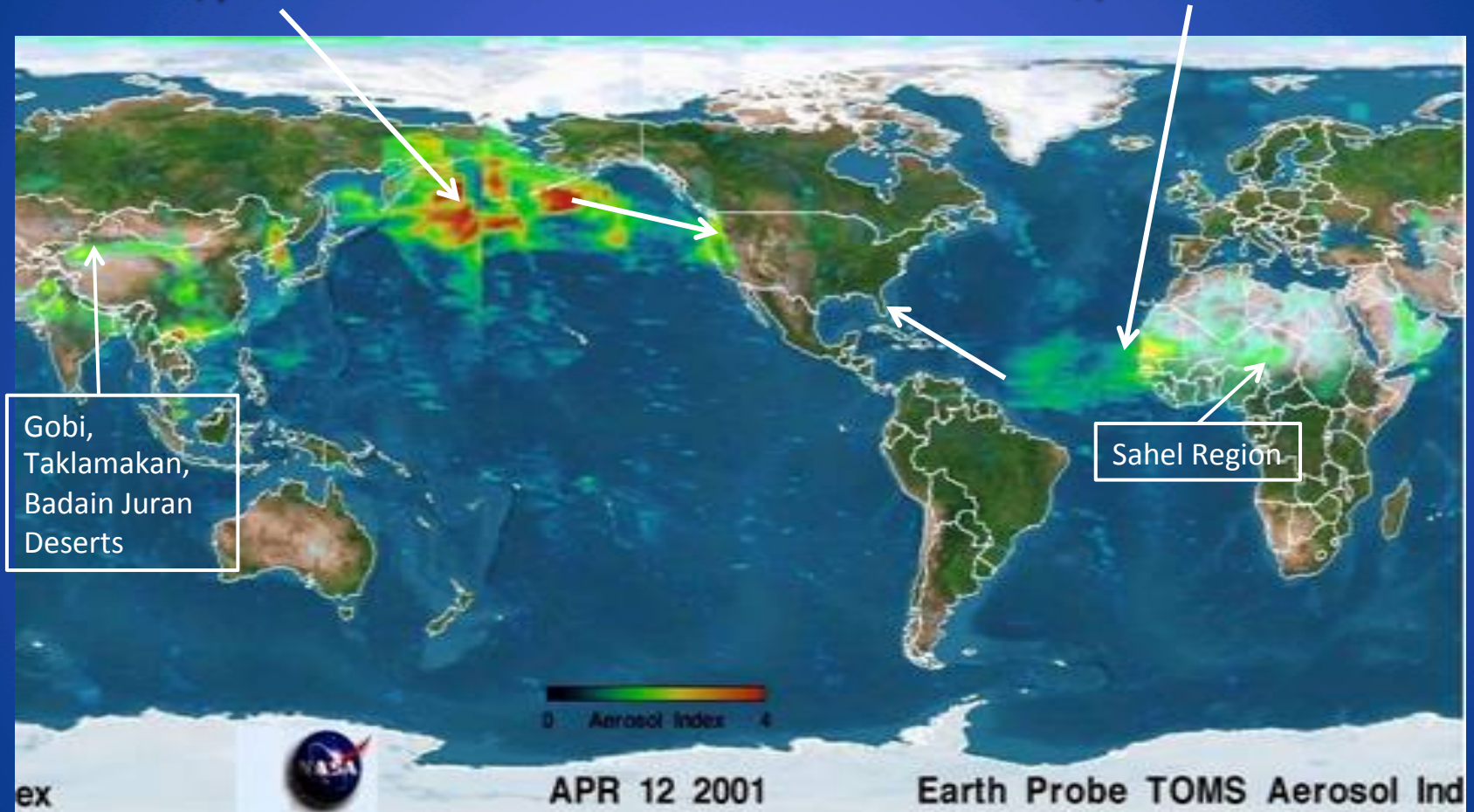
Andy Schuerger, UF



Global Dust Circulation Patterns

Peak = Feb. to April
56 Mt/yr reaches USA

African Peak = July to Sept.
50 Mt/yr hits Florida



Asian and African dust enters North America via two dust corridors (shown above) depositing in excess of 100 million tonnes/yr into the USA.

Science Questions (SQ) Relevant to Transoceanic Asian & African Dust

SQ1: Do microbial biodiversity and aerosol geochemistry differ between Asian and African dust plumes reaching North America?

SQ2: How does biodiversity and viability change between source regions and target ecosystems? And, what are the spatial and temporal fluctuations in biodiversity within arriving transoceanic dust plumes?

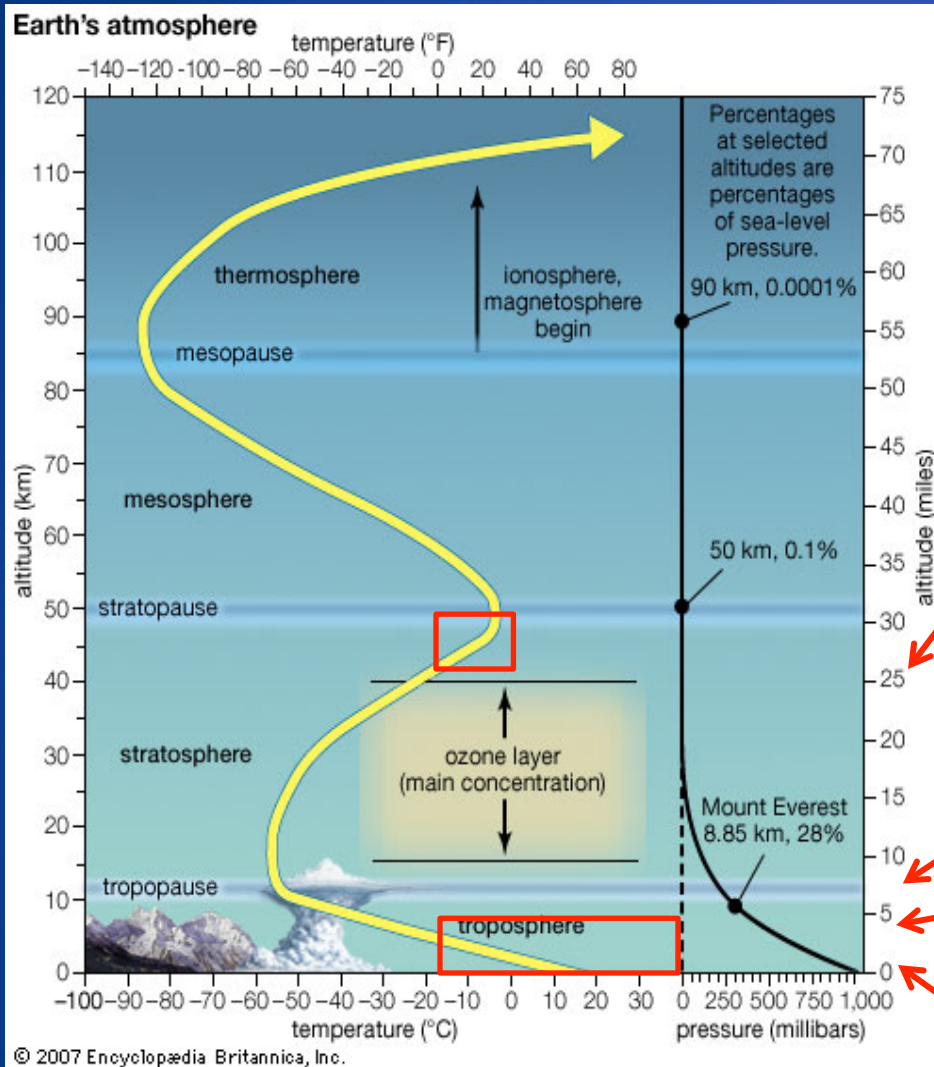
SQ3: Are transported microorganisms metabolically active during transoceanic transport?

SQ4: What are the ecological consequences to terrestrial and marine ecosystems in North America by microbial and dust deposition from transoceanic sources?

SQ5: Are human, animal, plant, or marine pathogens transported in Asian and African dusts?

SQ6: Can ground (e.g., up-looking LIDAR), aircraft, and satellite remote sensing measurements be used to develop a dust/microbial dispersal model for Asian and African dust plumes using aerosols as proxies for microbial biodiversity in transoceanic dust plumes?

Diverse Dust Sampling Technologies Target Different Altitudes



Balloons



C20A



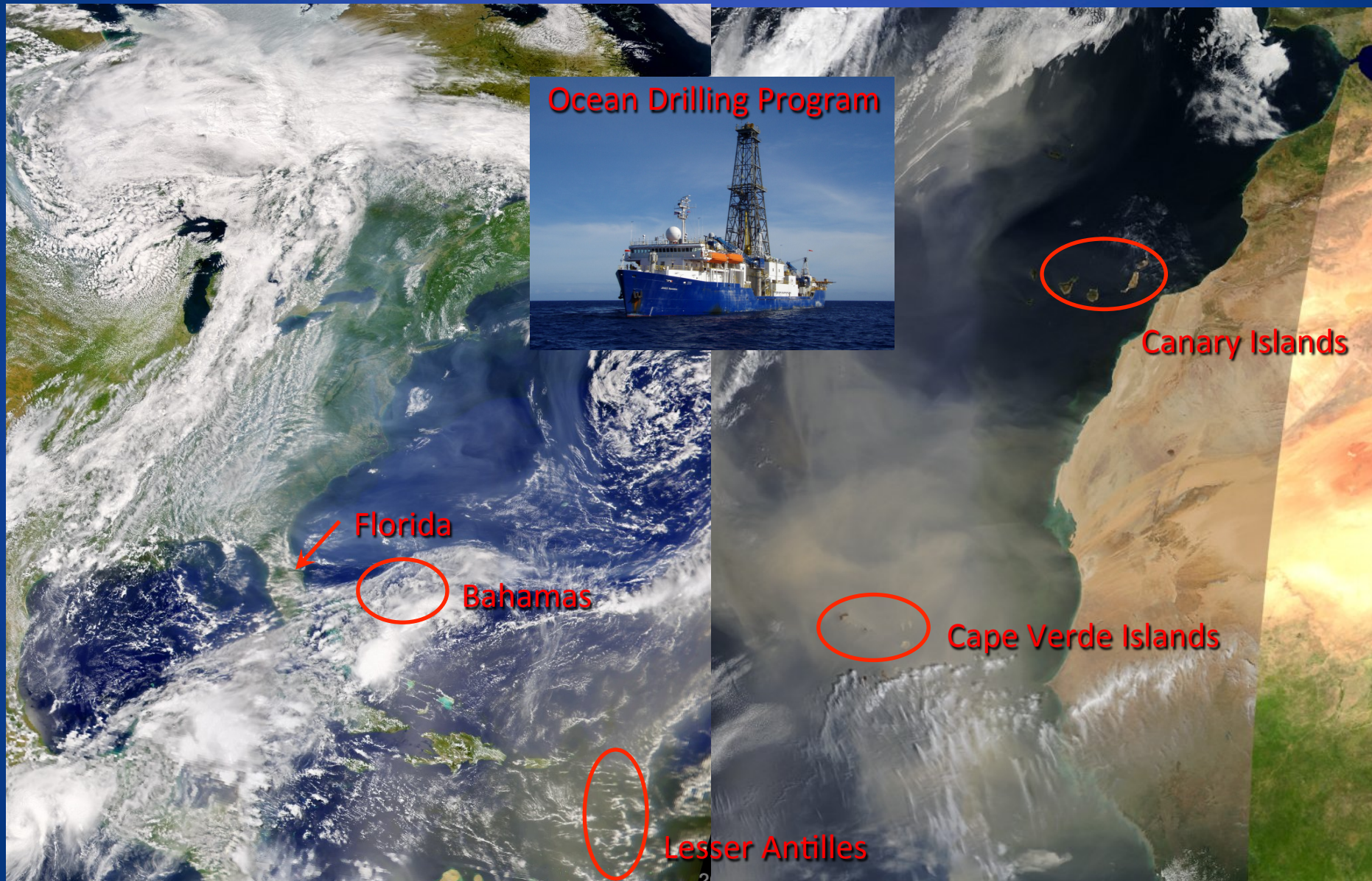
T6 Texan



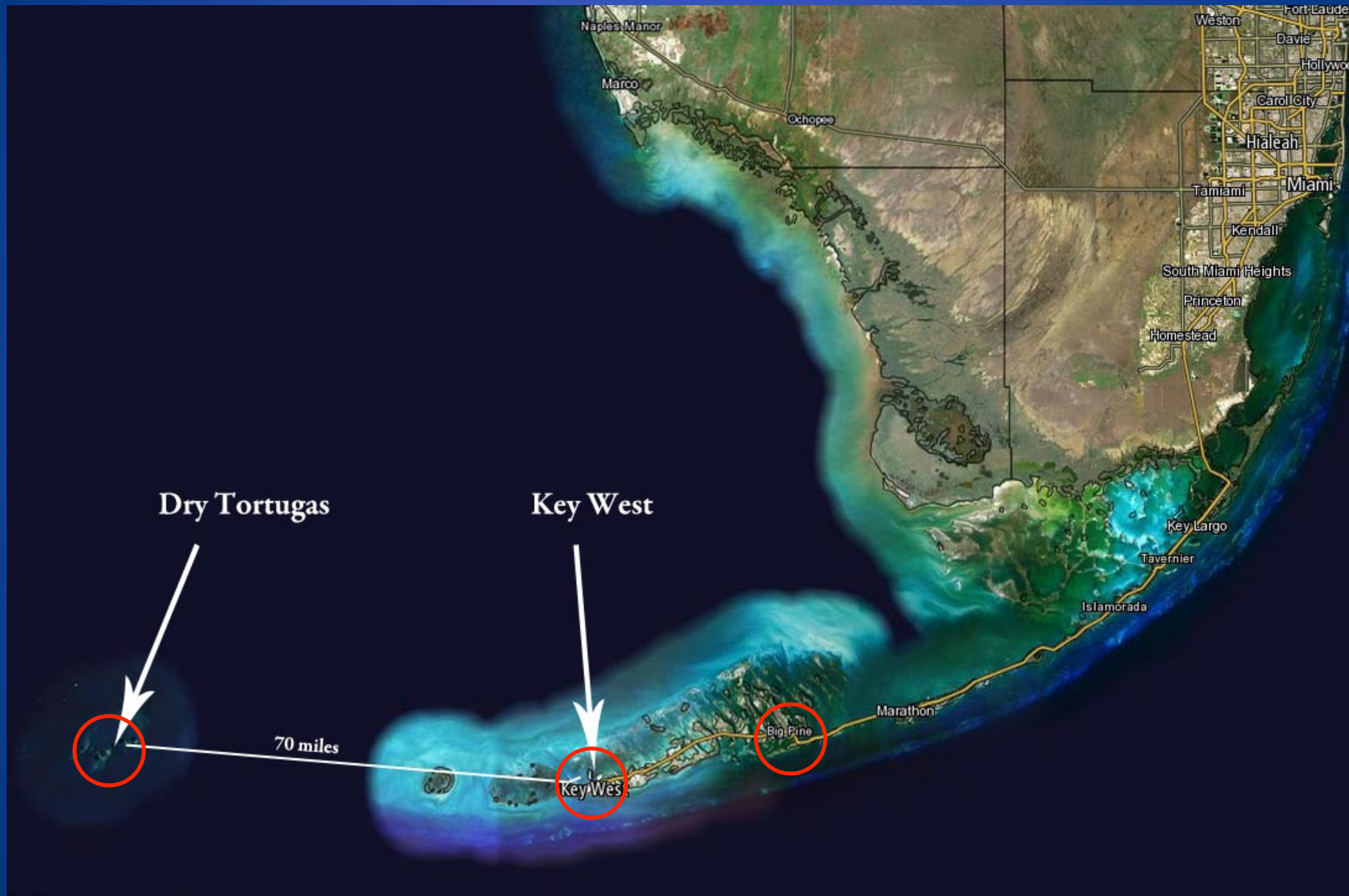
UAVs

Diverse aerial platforms are selected for science-specific missions depending on the target altitude to be sampled.

African Dust Field Sites



Ft. Jefferson and Key West Sampling Field Campaign.



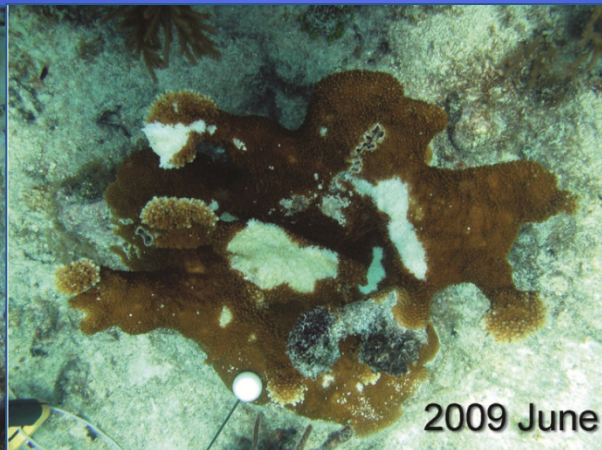
Ft. Jefferson and Key West Sampling Field Campaign.



Effects of Dust on Water Quality versus Coral Reef Health

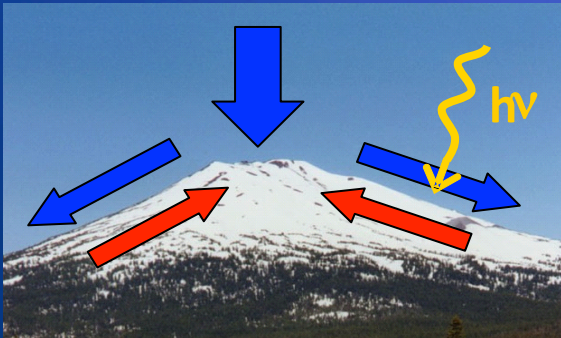
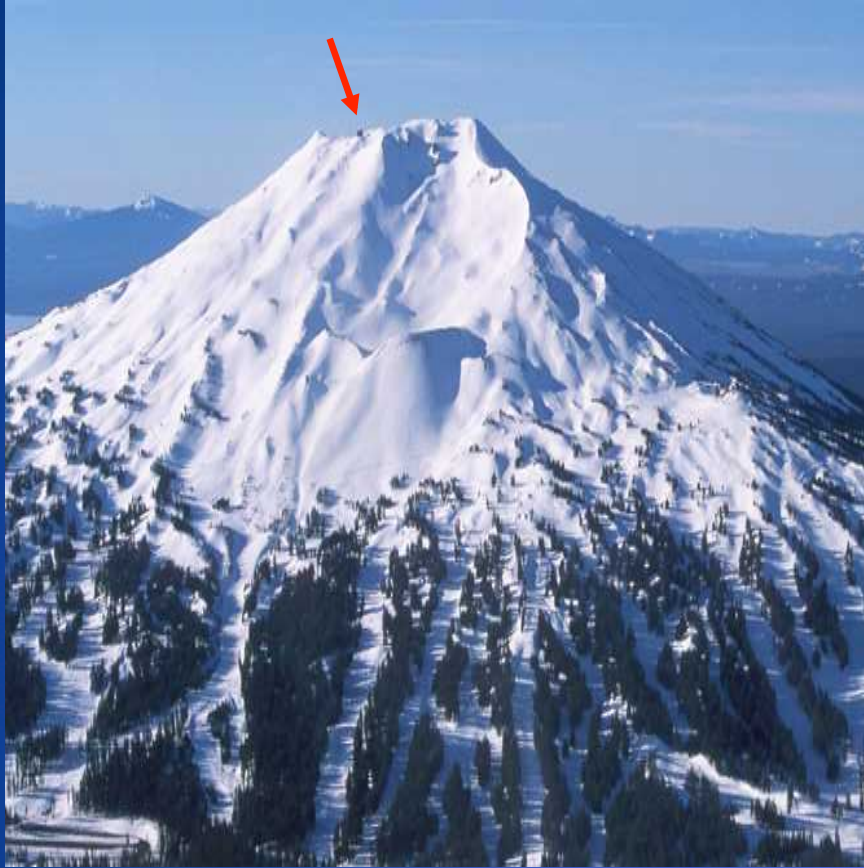


White Pox disease on Elkhorn Coral (*Acoropora palmata*)



Aspergillus sydowii on Sea fan Coral (*Gorgonia ventalina*)

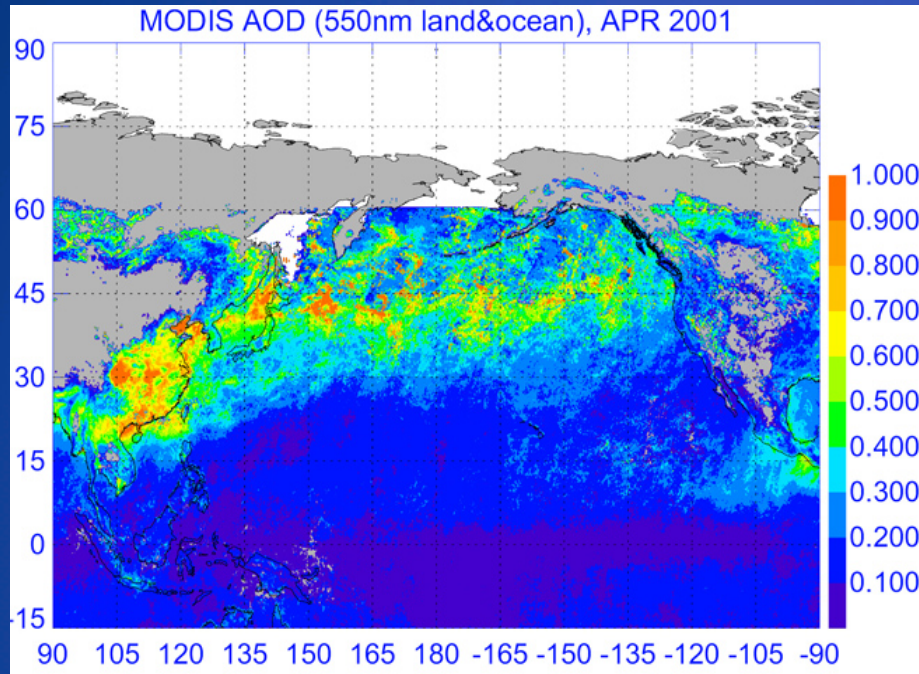
Asian Dust on Mt. Bachelor, Bend, OR



Day: upslope flow brings modified BL air to summit. This air is more humid and usually low in O_3 .

Night: downslope flows brings Free Tropospheric (FT) air to the summit. This air is dry and usually high in O_3 .

Satellite-based Assets to Predict and Track Transoceanic Dust



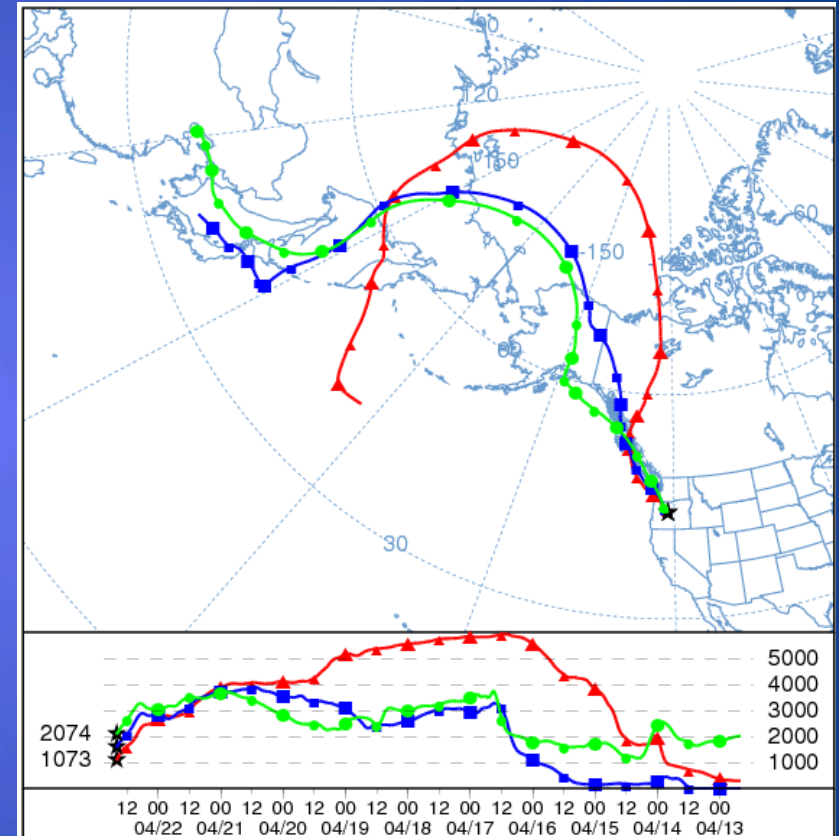
MODIS image of an Asian dust plume

For Predictive-Datasets:

➤ MODIS & VIIRS.

For Modeling Dust Plumes:

➤ GOES-16, GOES-R, MODIS, VIIRS, CALIOP, & CATS



Kinematic Back Trajectories
(from NOAA HYSPLIT)



SAS-DUO 360



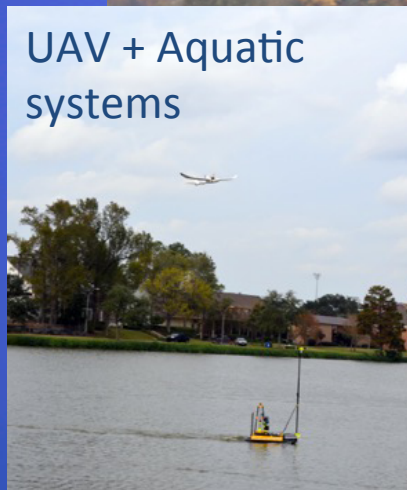
UAV systems



NASA/C20A Gulf Stream



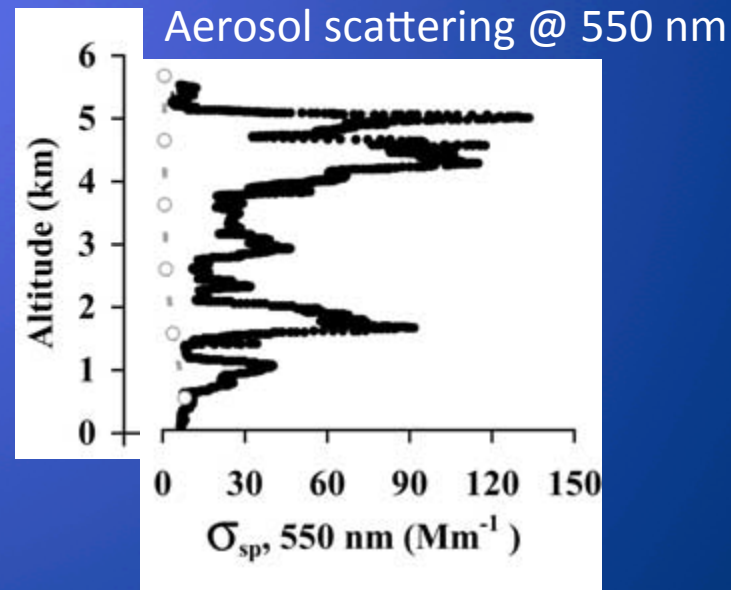
OMNI 3000



UAV + Aquatic systems



Smith et al., 2012

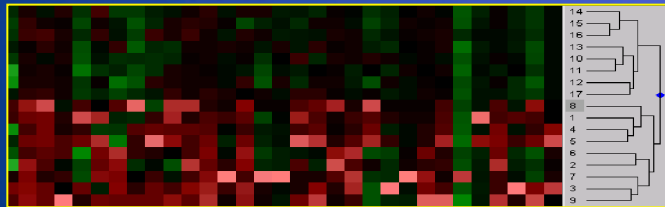


Aerosol scattering @ 550 nm

Bertschi & Jaffe, 2005

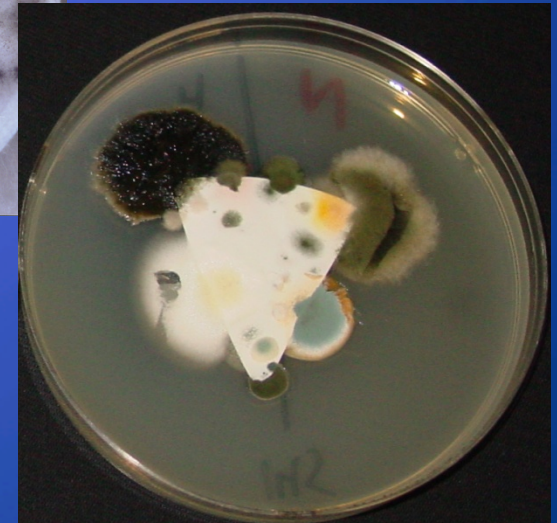
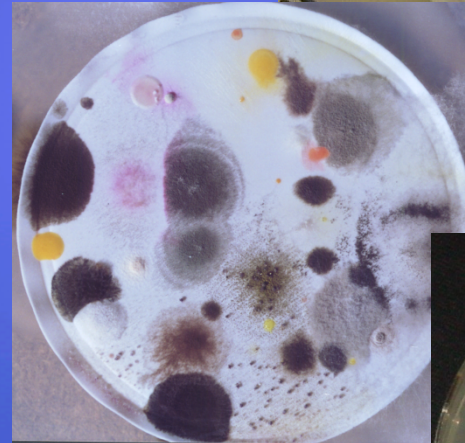
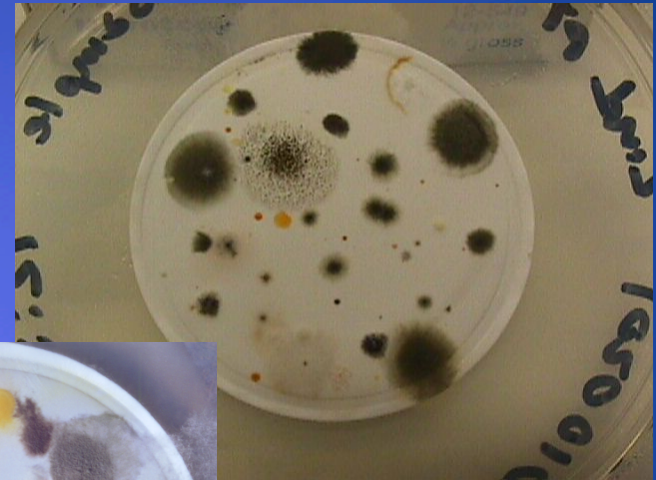
Microbial Assays for Bacteria, Fungi, Archaea, & Viruses

#1) What's there?

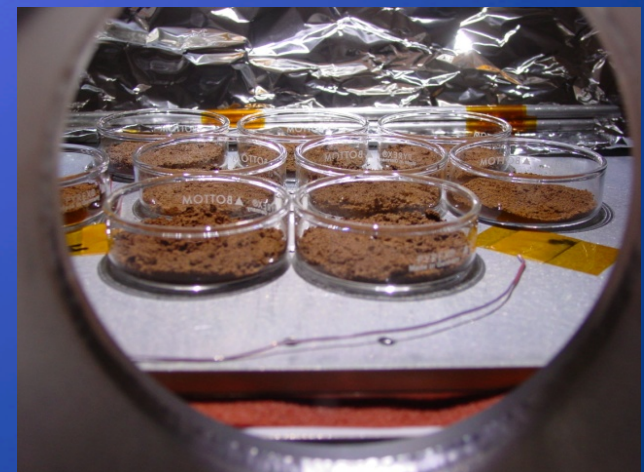
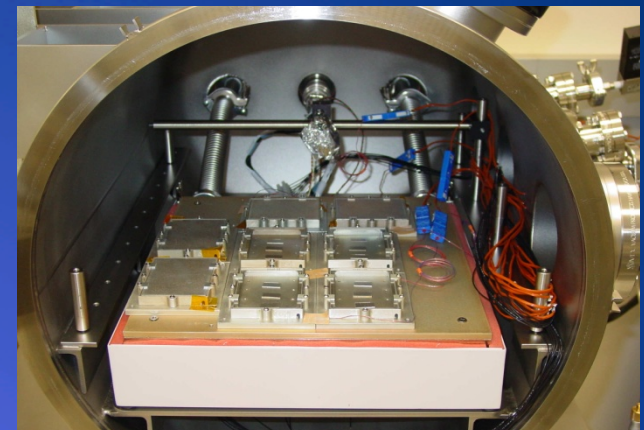
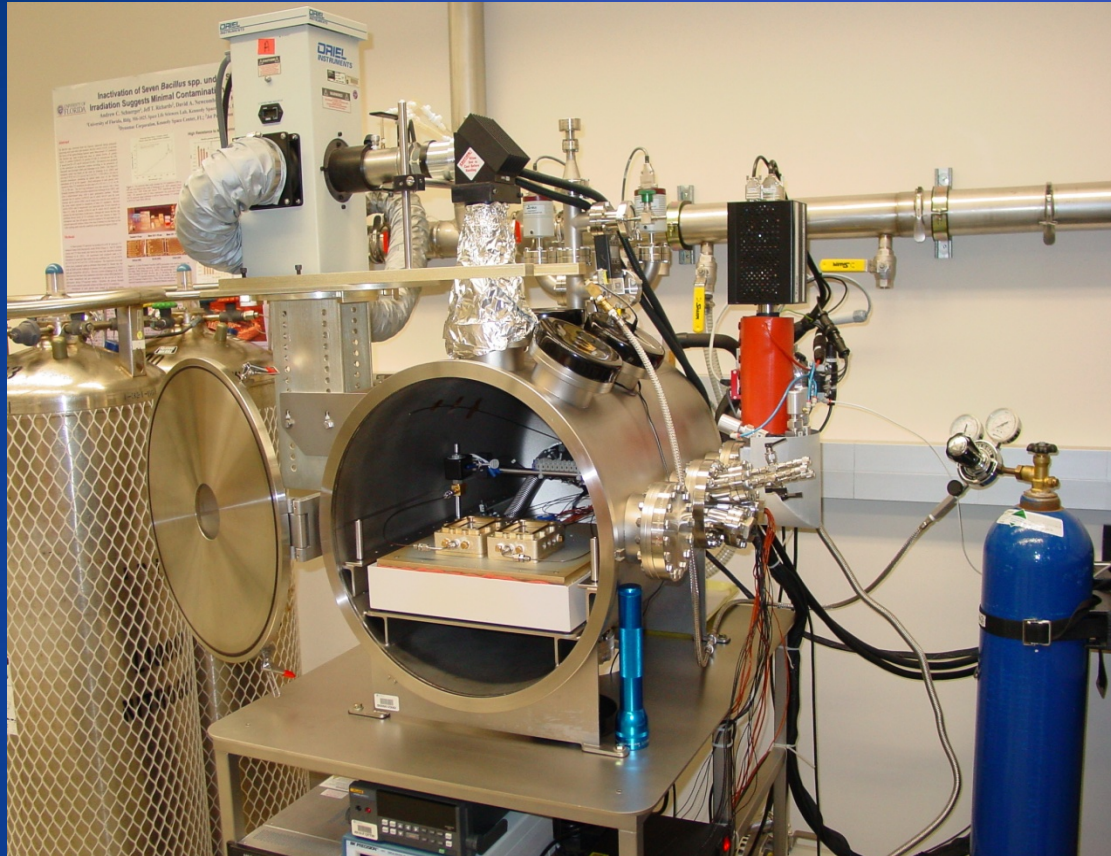


Phylochip technology = 8750 taxa.

#2) Recovery of Culturable Species.

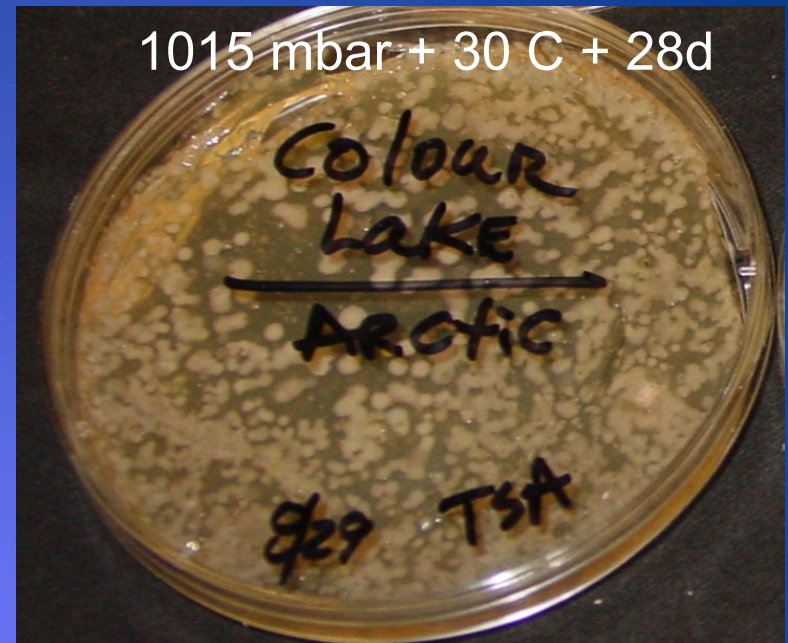
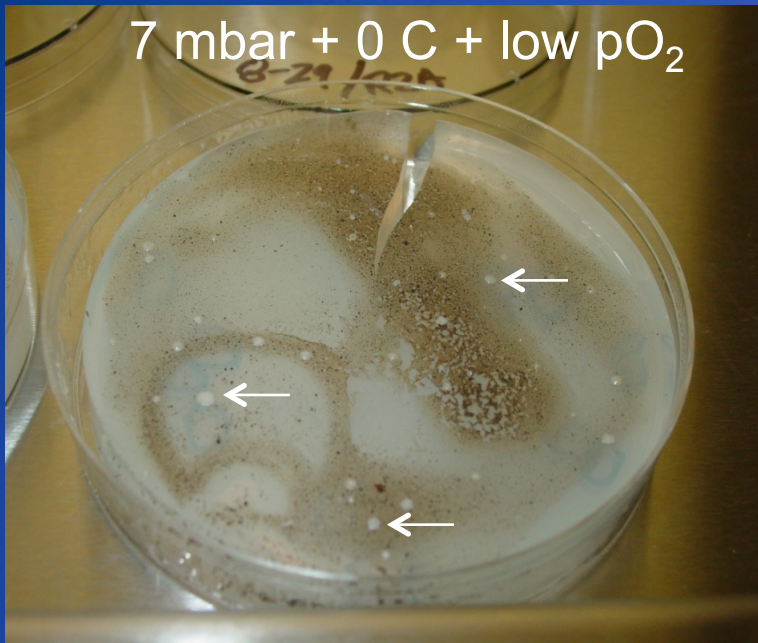


Microbial Survival, Growth, and Adaptation to Hypobaric Atmospheres



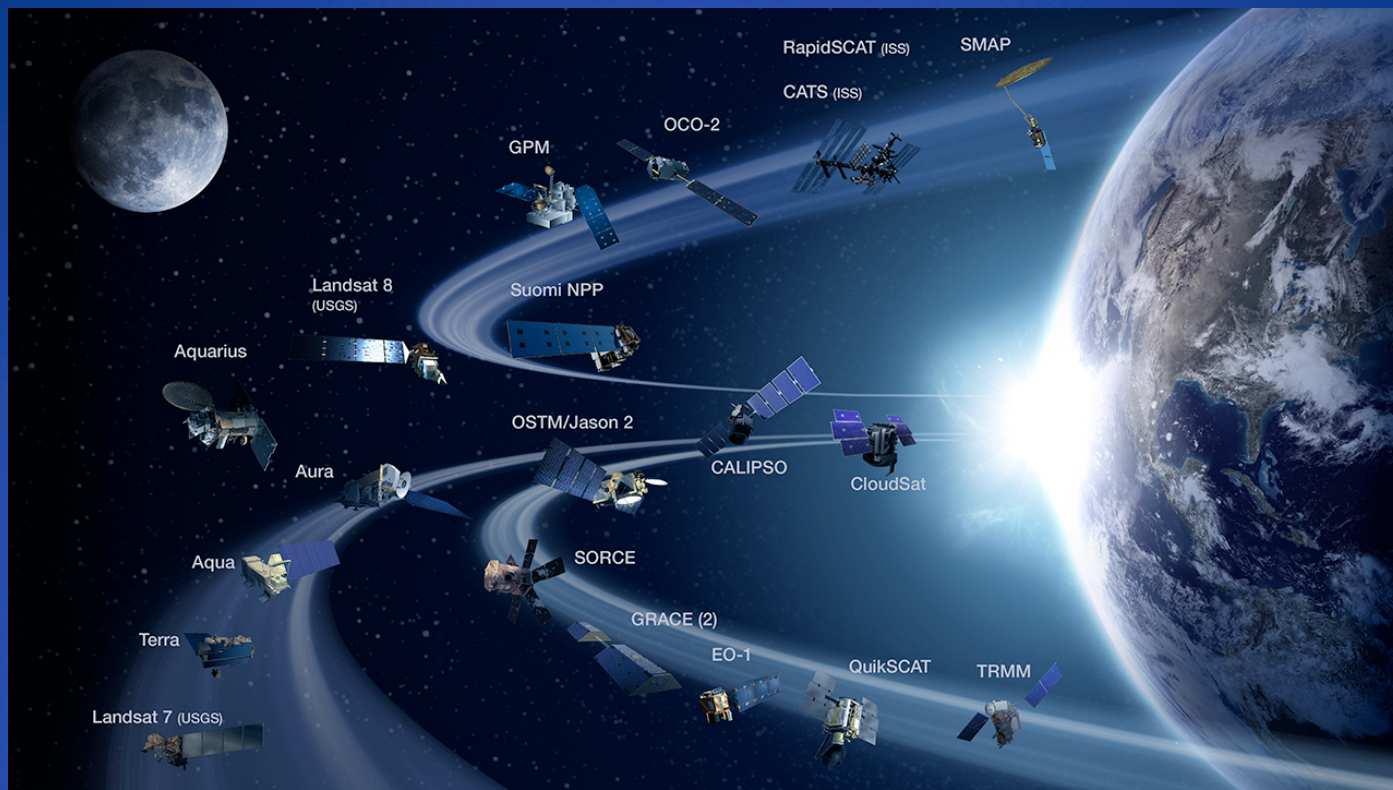
- Pressure: down to 0.1 mbar
- Temp: -100 to +160 °C (programmable)
- Gases: CO₂; O₂/N₂; Mars mix (top 5 gases)
- UV-VIS-NIR: equatorial to polar fluence rates
- Dust loading from τ 0.1 to 3.5

Environmental Samples Grown at Δ pressures, 0 °C, and CO₂ Atmosphere



31 Hypobarophilic bacteria species Identified to date:

- *Bacillus* sp. (1 species)
- *Carnobacterium* spp. (10 type-strains)
- *Clostridium* sp. (1 species)
- *Cryobacterium* sp. (1 species)
- *Exiguobacterium sibiricum*
- *Paenibacillus antarcticus*
- *Rhodococcus qingshengii*
- *Serratia liquefaciens* (+5 type-strains)
- *Streptomyces aureus* (+1 species)
- *Thrichococcus* spp. (3 species)



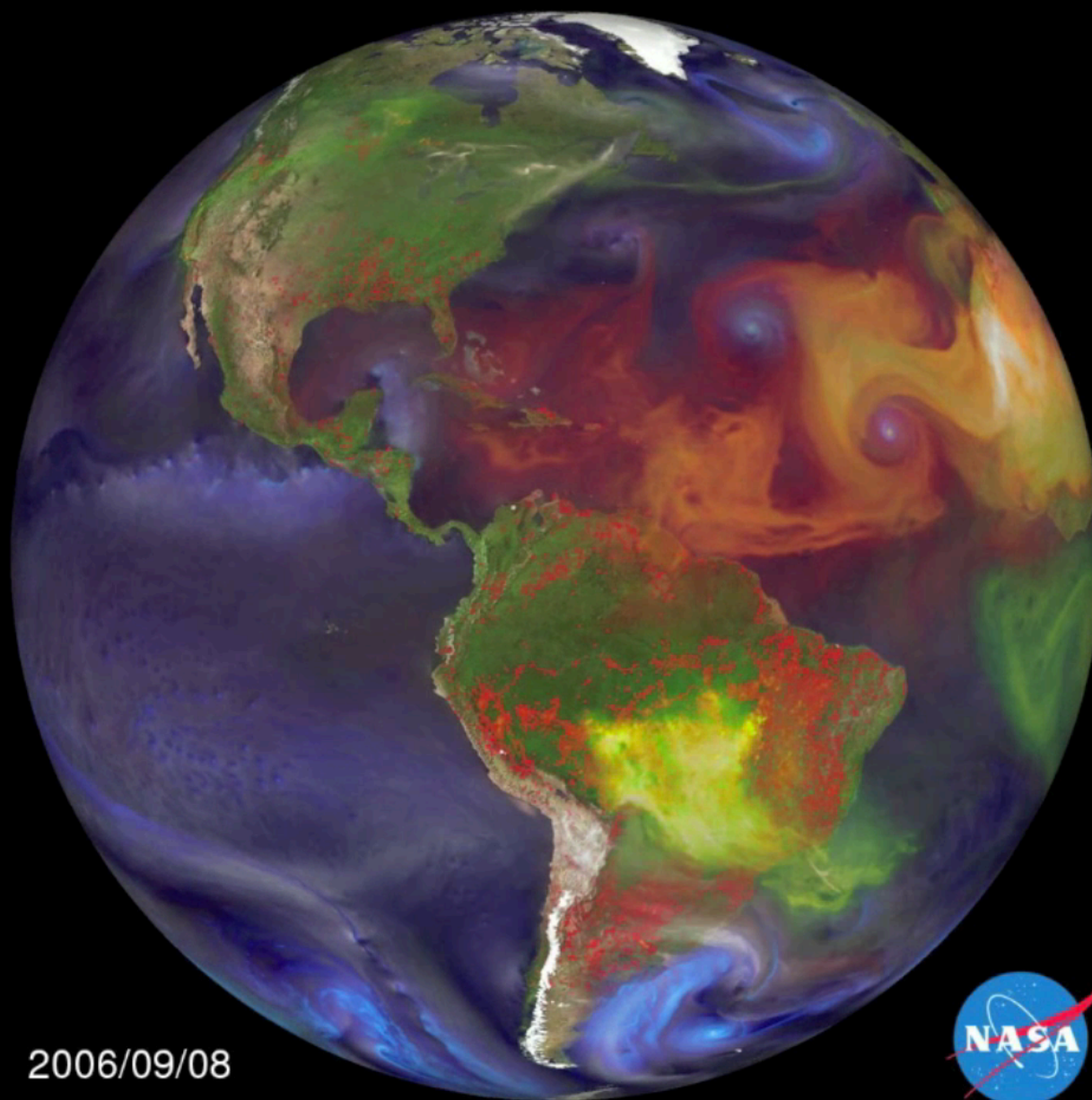
Integrate remote sensing and modeling tools to characterize trans-Atlantic and trans-Pacific dust transport for both *inflight planning and post-campaign data analysis*.

Satellite: VIIRS, EPIC/DSCOVR, ABI/GOES-R, GOES-16, CALIOP, & CATS.

Ground: AERONET, MPLNet, AD-Net, dust/PM network

Model: GEOS-5 (forecast & assimilation), HYSPLIT trajectory, other forecast models (NAAPS, WMO SDS-WAS)



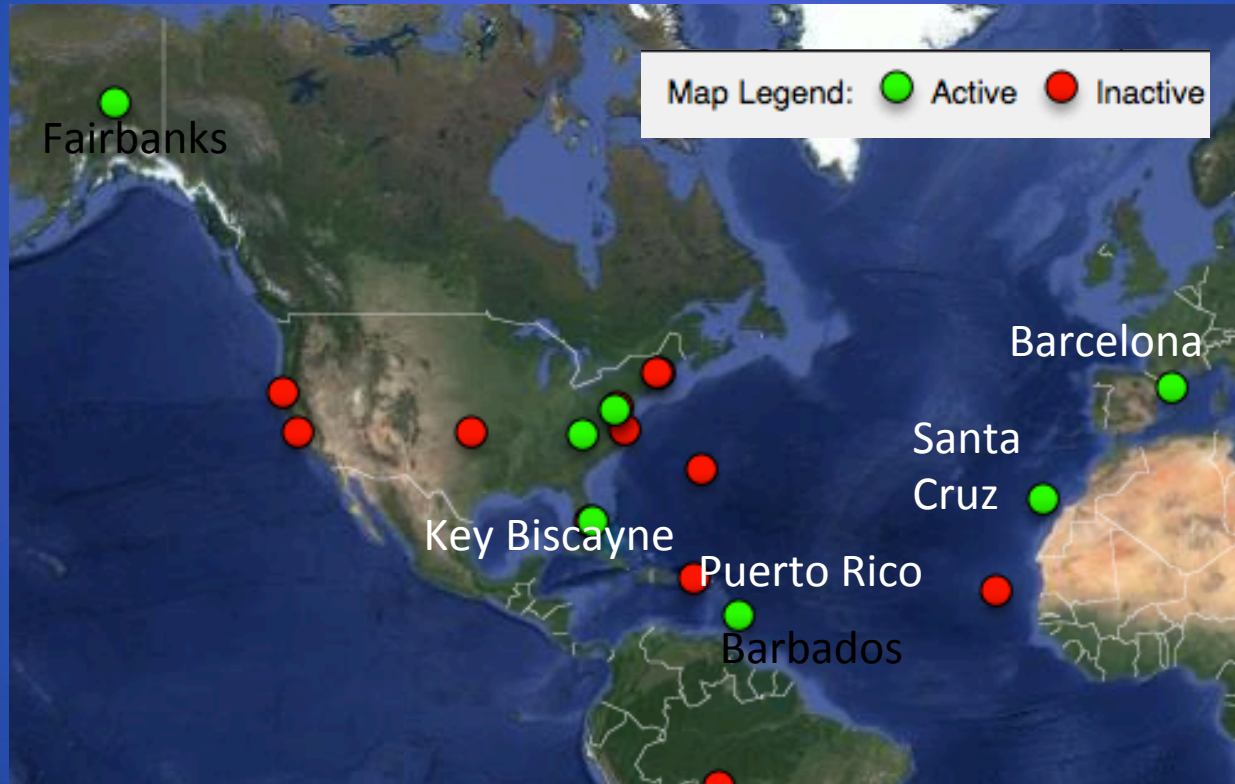


2006/09/08



Existing LIDAR System: NASA MPL-Net

- A federated network of Micro-Pulse Lidar (MPL) systems
- Co-located with AERONET sites (providing constraint for lidar retrieval)



- Some LIDAR systems in tropical Atlantic can be useful for Florida campaign (assuming they will remain active in next 5 years).
- No LIDAR system exist in west coast for Oregon campaign.

Ice Cores: Archives of Atmospheric Dust and Precipitation

Environmental Data Include:



- A** Temperature ($\delta^{18}\text{O}$)
- B** Atmospheric Chemistry
- C** Net Accumulation
- D** Dustiness of Atmosphere
- E** Vegetation Changes
- F** Volcanic History
- G** Anthropogenic Emissions
- H** Entrapped Microorganisms

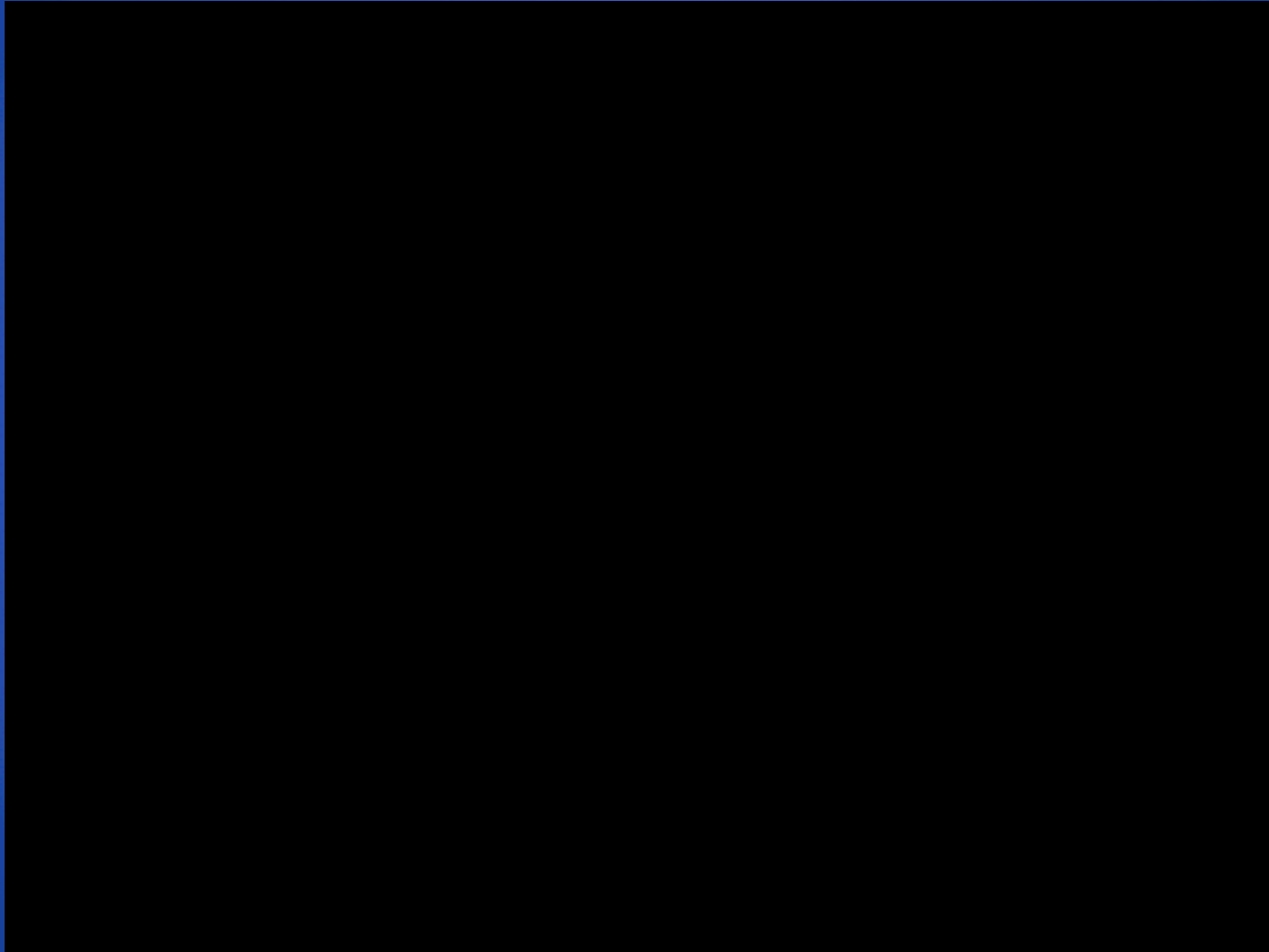


NICL, Denver, CO



Can Transoceanic Dust be used as a Proxy for a Microbial Dispersal Model?

NASA Center for Climate Simulation, GOES-5 data, Goddard Space Flight Center



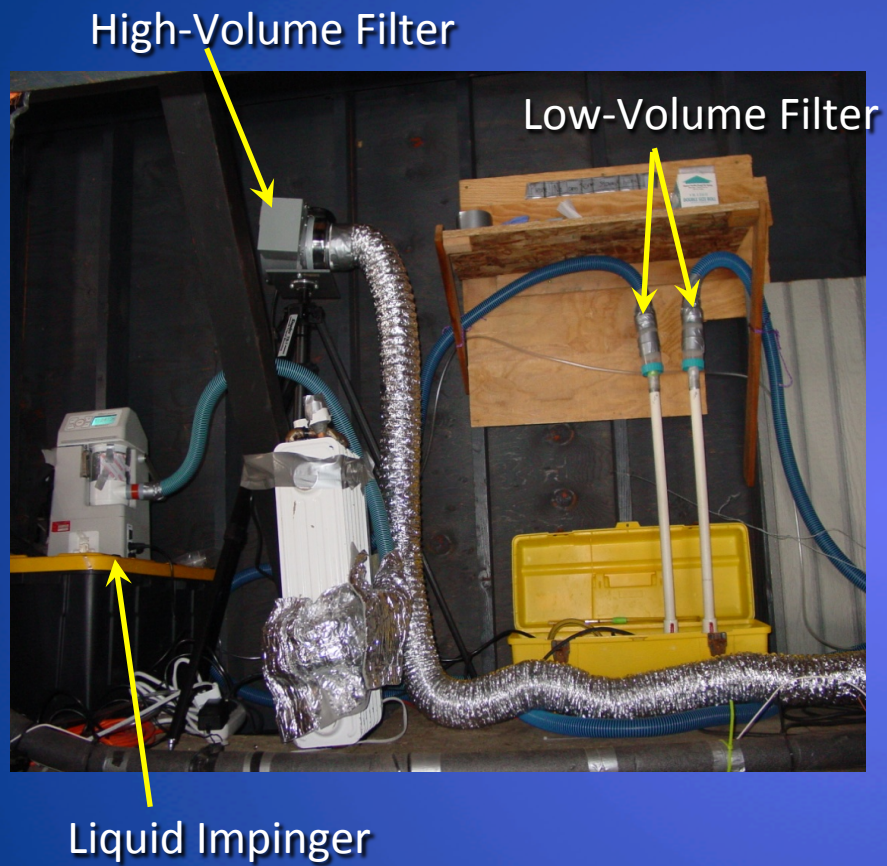
Dust (orange) lifted from the surface, sea salt (blue) swirls inside cyclones, smoke (green) rises from fires, and sulfate particles (white) stream from volcanoes and fossil fuel emissions.

SQ1: Do microbial biodiversity and aerosol geochemistry differ between Asian and African dust plumes reaching North America?

Knowledge Gaps

- 1) What are the optimum sampling protocols for aerial collection of Asian versus African dust plumes?
- 2) What molecular approaches are appropriate to detect microbiota in low biomass aerial samples?
- 3) Can biological, geochemical, or physical markers in dust plumes be used to distinguish transported microbiota from local sources?
- 4) How do atmospheric chemistry, dust geochemistry, and organic carbon composition affect the survival rates and/or growth of microorganisms during transit?
- 5) Are microorganisms transported attached to dust particles, or are microbial cells and spores transported as free-floating particles?

Mt. Bachelor, Bend, OR

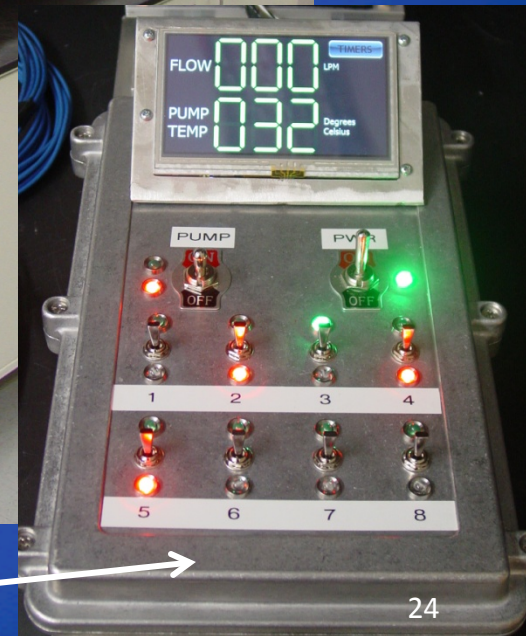


DART External Housing

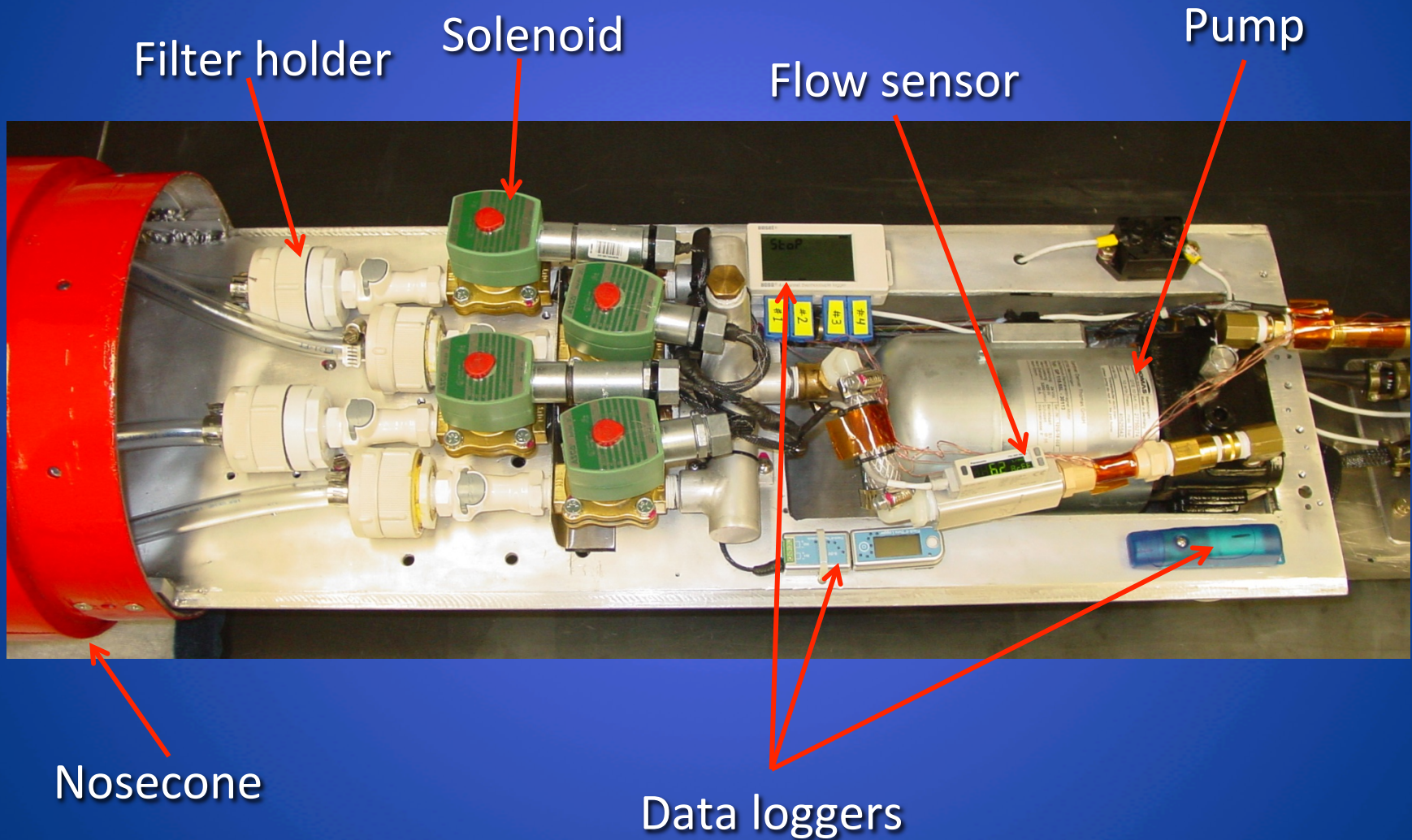
Scoop door open.



Control box sits in crewed cockpit.



DART Internal Subsystems



DART/F104 Starfighter Jet Test Flights---Dec. 2013



DART was successfully flown on the F104 up to 0.92 Mach, 35,000 ft, and 3.5 +G's. 26

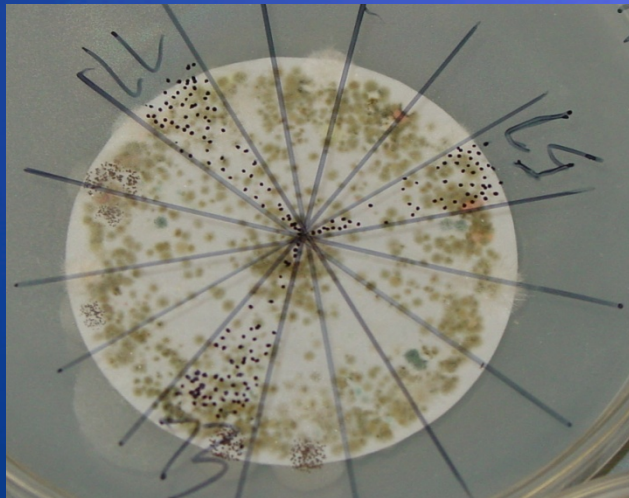
DART/T6 Texan Flights Oct/Nov 2014



DART sampling
airborne dust over
KSC; Nov. 11, 2014.

DART was successfully flown on the T6 up to 140 KIAS, 12,000 ft and 5.2 +G's.

DART/T6 Preliminary Filter Integrity Results:

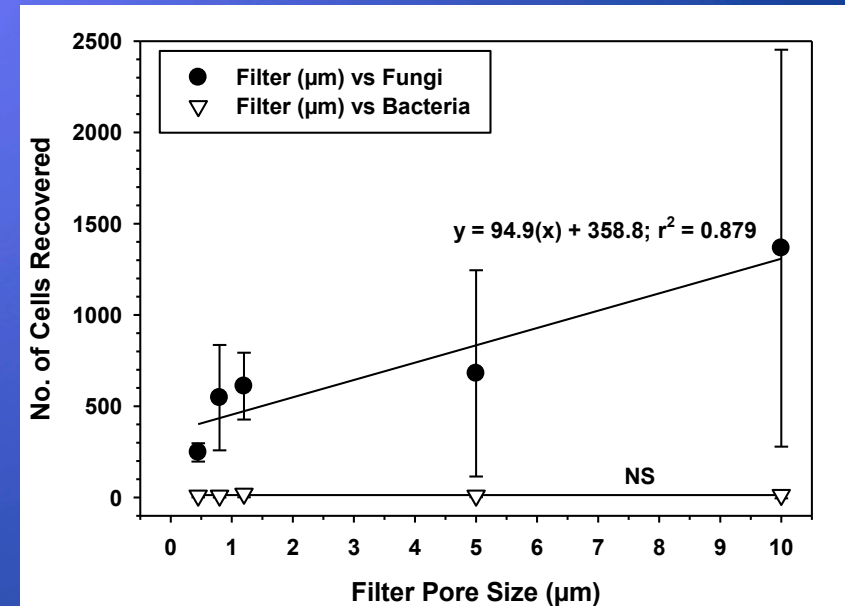
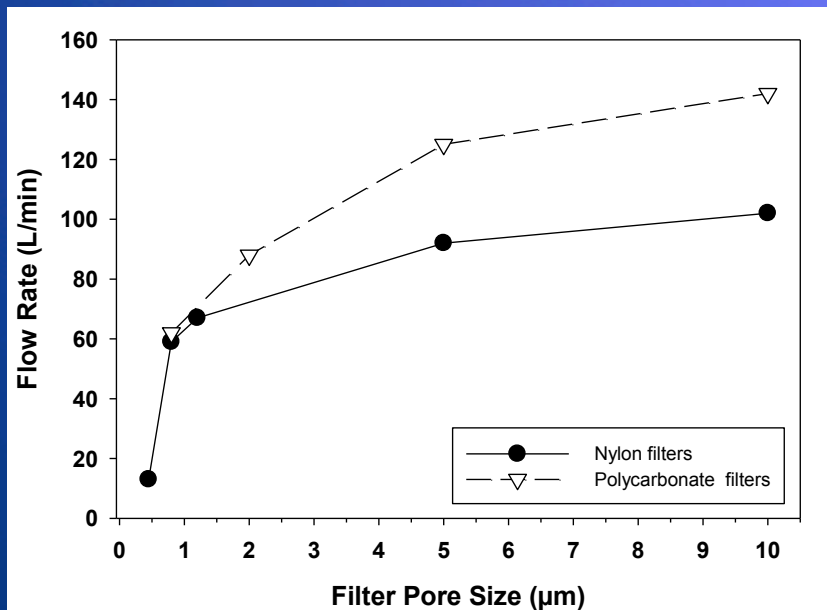


- Not all filter types work; nitrocellulose filters deformed and burst at 1500' and above.
- 5.0 μm nylon filters proved to be the most resilient.
- >78 fungal colonies.
- >30 fungal colony morphologies.
- >10 bacterial colony morphologies
- 16S & ITS sequencing completed.

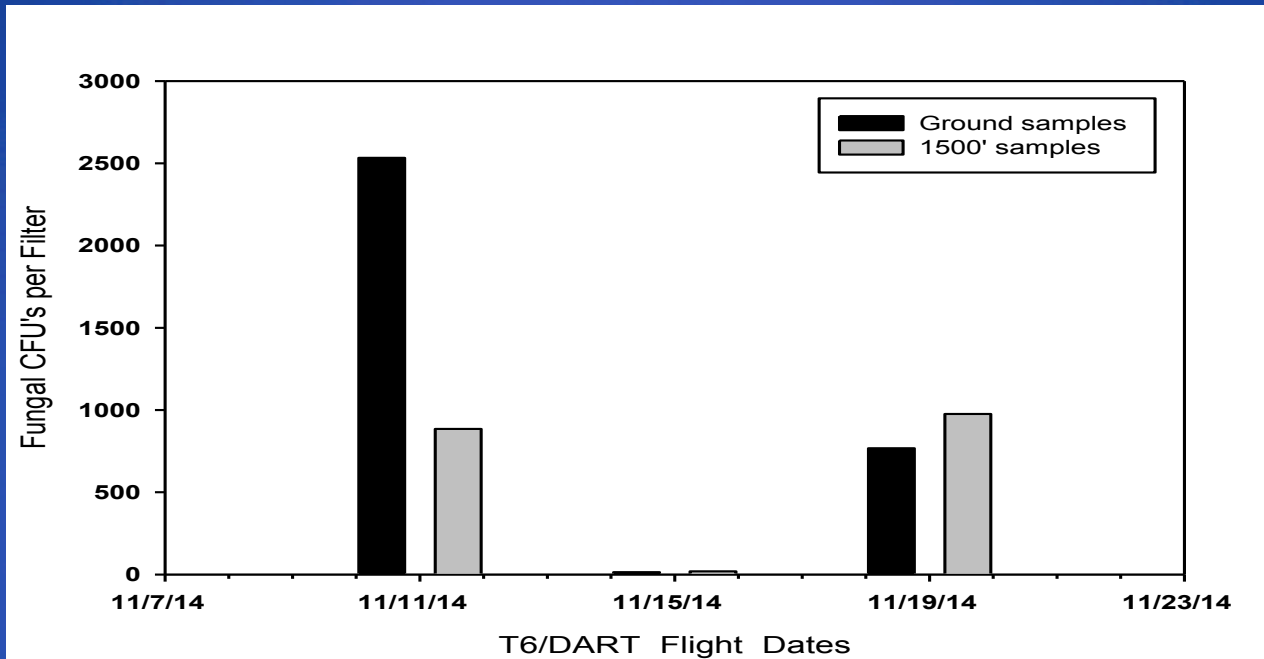
DART/T6 Preliminary Results:



- Airflow rates through filters were very stable at all altitudes tested.
- Airflow through filters decreased with increased altitude.
- Fungal cells recovered were positively correlated to increased filter pore-size.
- Bacteria recovered were not correlated to filter pore-size.

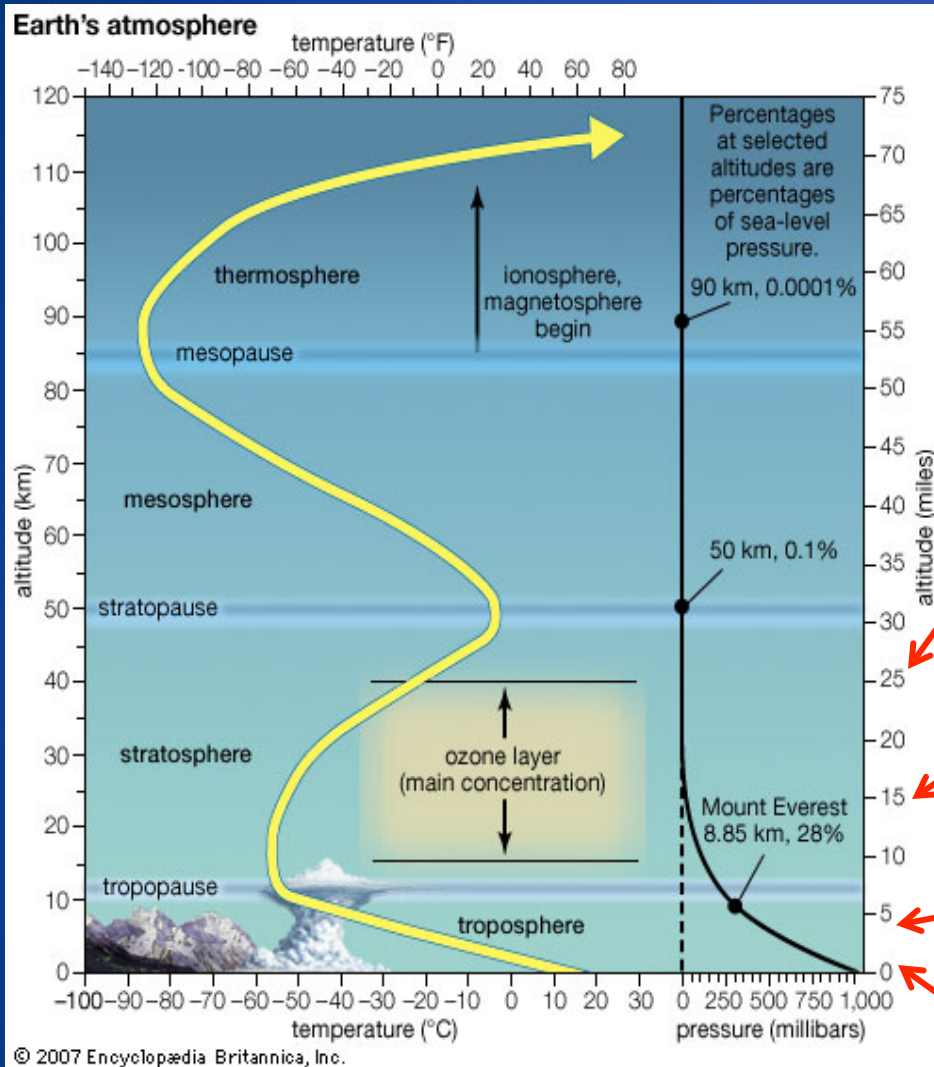


DART/T6 Preliminary Test-Flight Results:

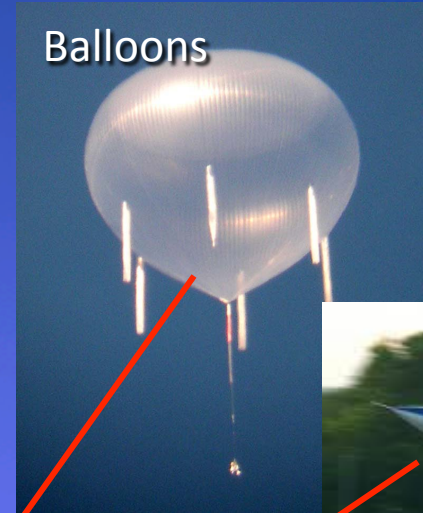


- 1) Within the planetary boundary layer (PBL), the numbers of recovered fungi (cells per filter) were similar between the ground and flight (at 1500 ft) samples.
- 2) *Cladosporium* spp. dominated both the ground and flight samples.
- 3) Microbial diversity was slightly higher in flight samples at 1500' compared to hangar samples.
- 4) ITS and 16S sequencing was completed on all recovered fungi and bacterial species.

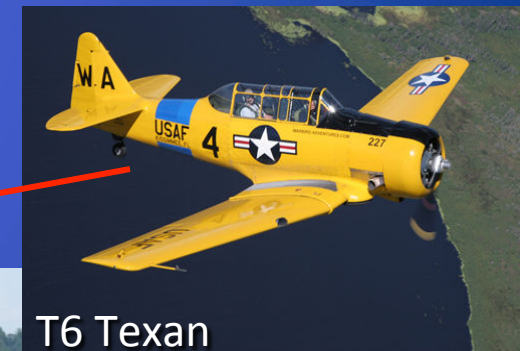
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